Marshall Space Flight Center and the open-source radar software revolution

Timothy J. Lang

Brenda Dolan, Brody Fuchs, Paul Hein, Elizabeth Thompson

Scott Collis, Jonathan Helmus

Nick Guy

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Jason Burks, Steve Nesbitt,
George Priftis, Brent Roberts
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Background

My radar software history …

Graduate School – RDSS, Reorder, SPRINT, Fortran, and pltgks

Research Scientist – IDL, solo, Reorder, SPRINT

NASA Civil Servant (2012) – Stick with IDL or go Python?

NASA Marshall's Lightning Group is mostly an IDL shop

But folks are receptive to Python and some want to learn!

I made the switch in early 2014

MSFC Science Goals

1. Understand lightning production in extreme weather events – *GLM, ISS-LIS*

2. Validate precipitation estimates from space – *GPM*

3. Study how well scatterometers characterize convective variability – *RapidScat, CYGNSS*

Open-source radar software, powered by Python, plays a prominent role in all of these tasks!

Marshall MRMS Mosaic Python Toolkit (MMM-Py)

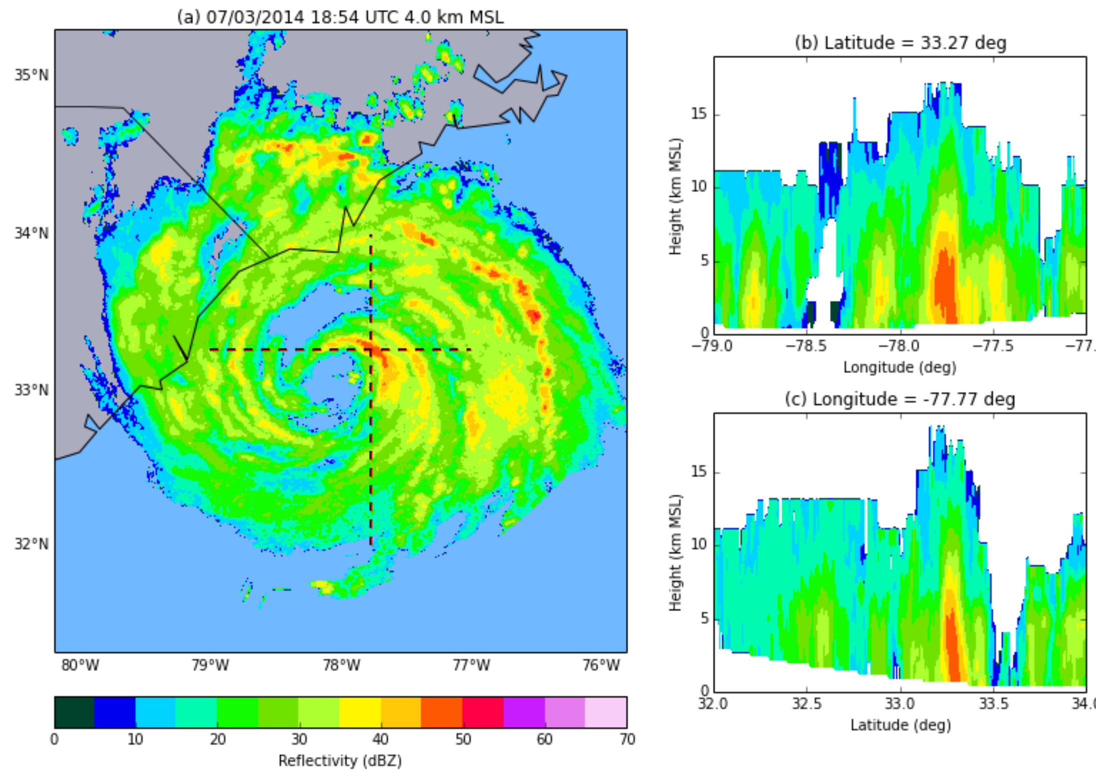
https://github.com/nasa/MMM-Py

<u>Goal</u>

Simplify the ingest, analysis, and display of NOAA MRMS 3D radar reflectivity mosaics in a Python environment

<u>Features</u>

- Can read any format MRMS, from 2009 onward
- Easy tile merging and domain subsetting
- Customizable plotting methods
- Save custom mosaics to file
- Demonstration Jupyter notebooks available



Python Turbulence Detection Algorithm (PyTDA)

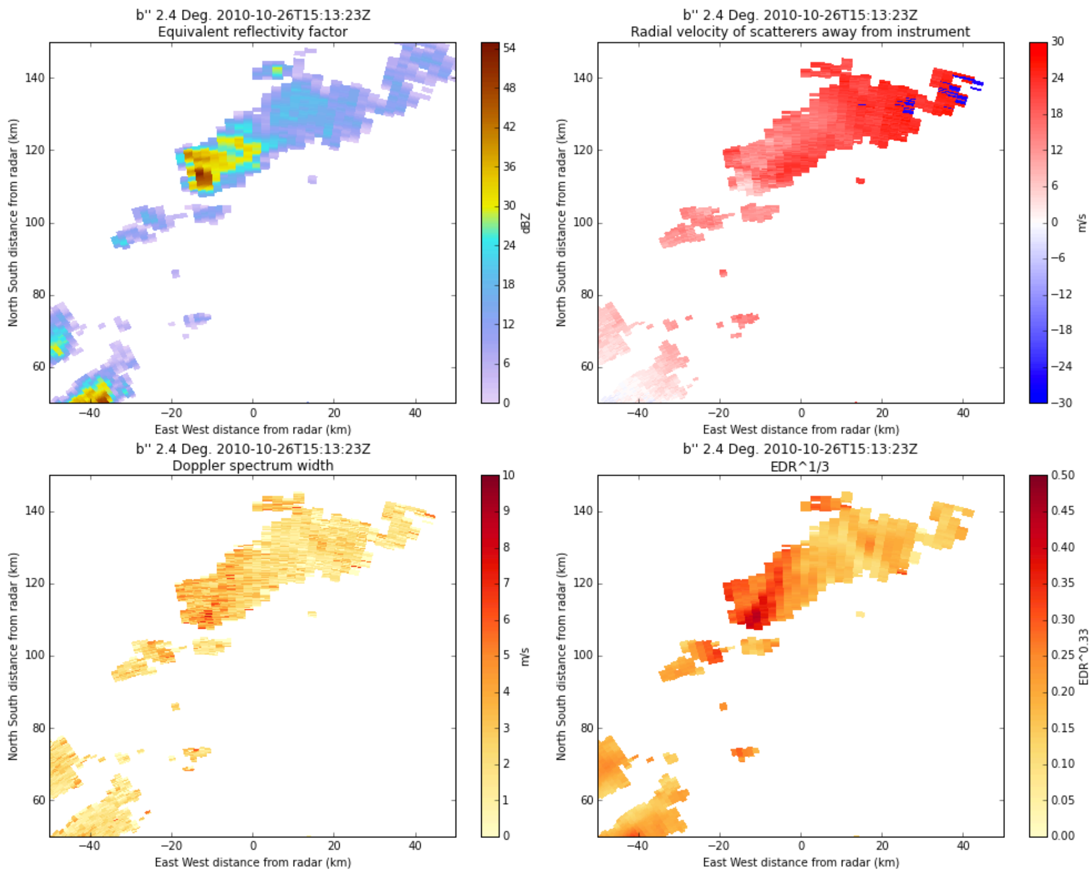
https://github.com/nasa/PyTDA

Goal

Estimate eddy dissipation rate (EDR) from arbitrary Doppler radar sweep or volume

Features

- Module contains independent functions for processing
- Works seamlessly with Py-ART Radar object
- NTDA-like filtering and quality control of data if desired
- Uses sklearn trees, NumPy function broadcasting, and some Cython to allow near real-time use on a laptop



Single Doppler Retrieval Toolkit (SingleDop)

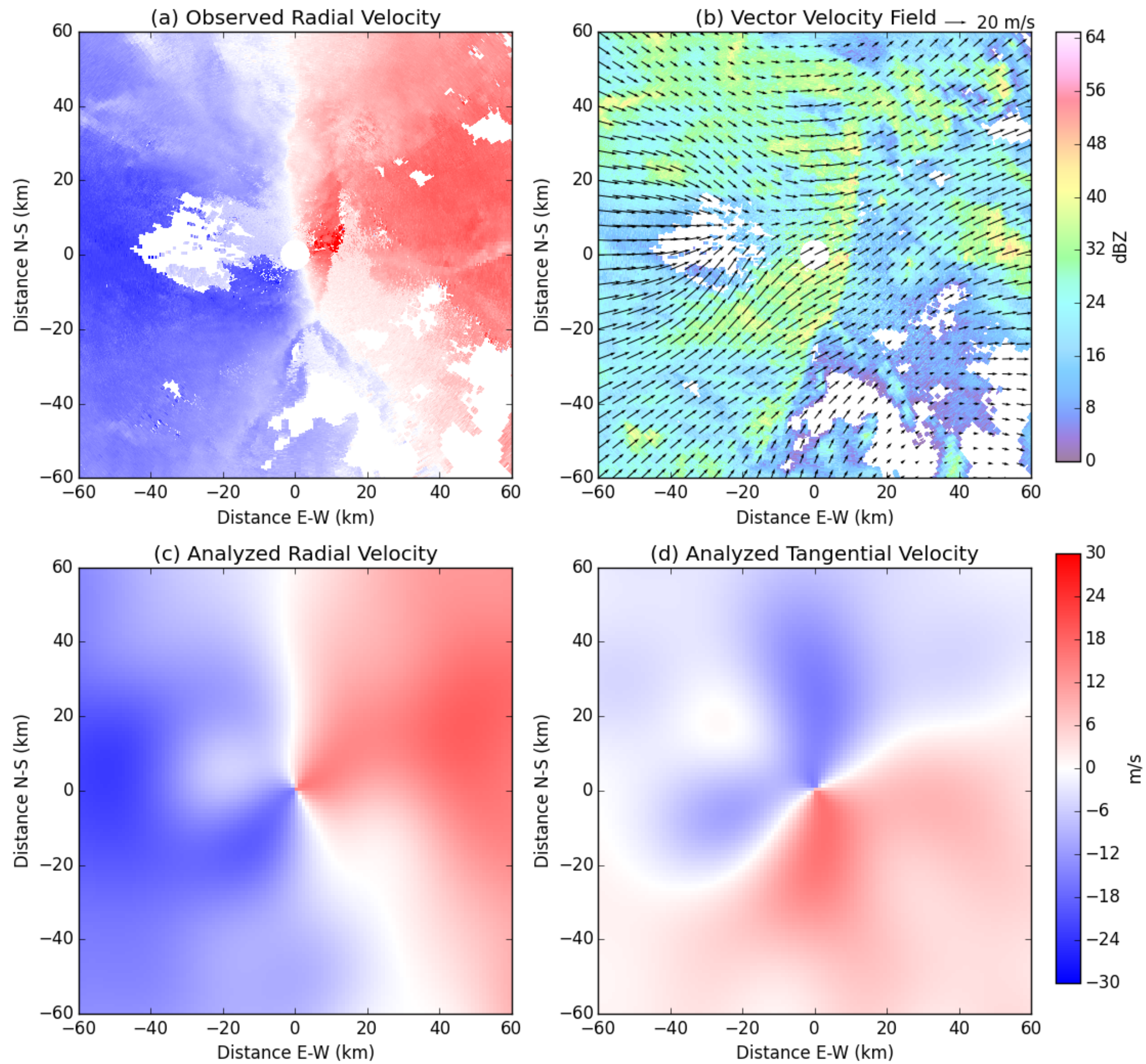
https://github.com/nasa/SingleDop

Goal

Estimate low-level 2D winds from single Doppler radar

Features

- Xu et al. (2006) method
- Works with real or simulated radar data
- Background field can be specified or determined via VAD
- Uses Py-ART for data input and display
- Output gridded analyses to Python-readable binary (pickle) or netCDF (xray)
- Contour, vector, and mixed multi-panel plots supported



Colorado State University Radar Tools (CSU_RadarTools)

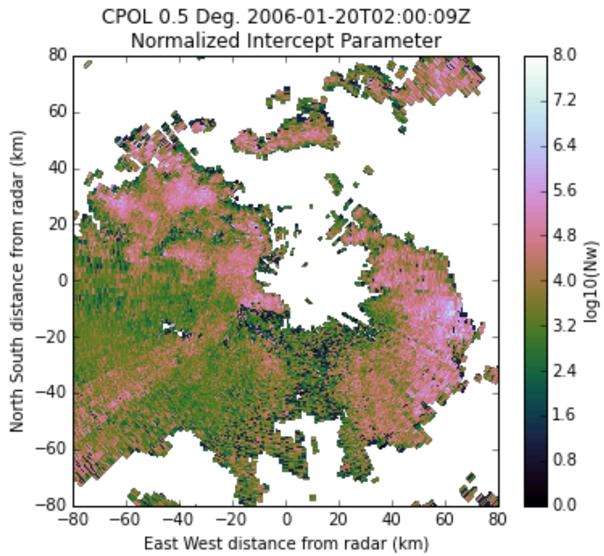
https://github.com/CSU-Radarmet/CSU_RadarTools

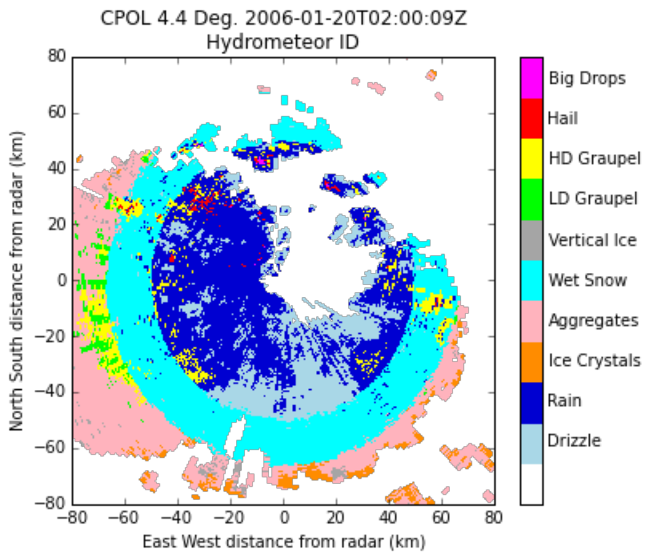
Goal

Provide routine polarimetric radar analysis and QC tools originally developed/used at CSU

Features

- Independent of any other software framework
- Works with ndarrays or scalars
- CSU Fuzzy-Logic Hydrometeor ID (X, C, S-band)
- CSU Blended Rainfall Calculations
- CSU Ice and Liquid Water Mass calculations
- CSU Drop-Size Distribution calculations
- CSU KDP calculations (FIR based)
- Miscellaneous QC (insect filter, despeckling, etc.)
- Each works as importable sub-module
- Thorough demo notebook available, shows how to use with SkewT and Py-ART.





Python Interface to Dual-Pol Radar Algorithms (DualPol)

https://github.com/nasa/DualPol

Goal

Simple workflow for merging CSU_RadarTools with Py-ART

Features

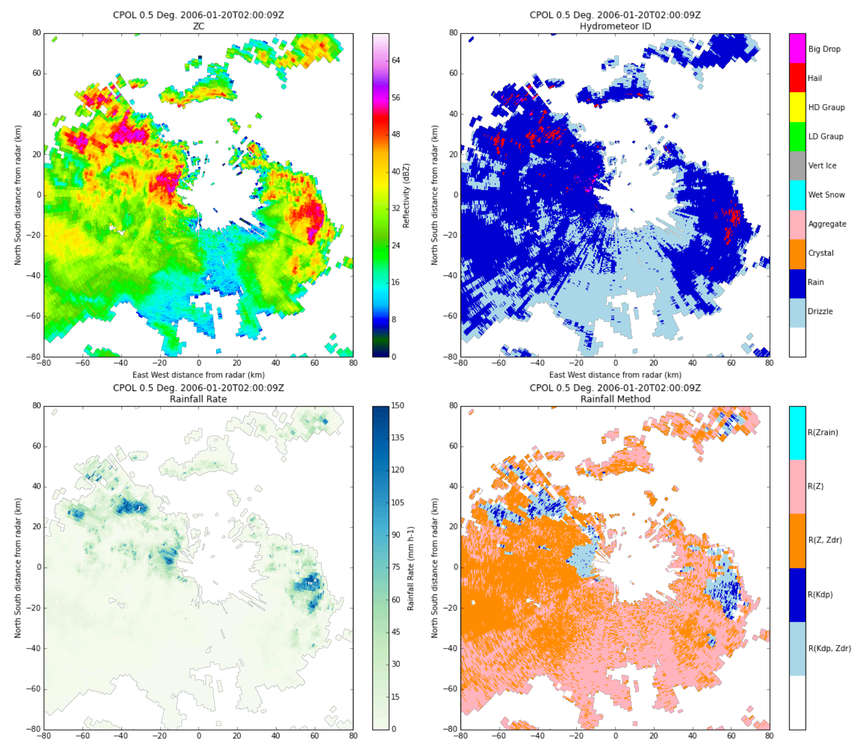
- One-line implementation for dual-pol retrievals and integrating them within Py-ART radar object
- Class that simplifies display of HID & rain method colorbars

In [4]:
```
sndfile = '/Users/tjlang/Documents/OVWST/CPOL/soundings/snd_Darwin.txt'
retrieve = dualpol.DualPolRetrieval(files[0], dz='ZC', dr='ZD', kd='KD', rh='RH',
                                    use_temp=True, band='C', fhc_method='hybrid',
                                    sounding=sndfile, fhc_T_factor=2,
                                    ice_flag=True, rain_method='hidro')
```

In [5]:
```
print retrieve.radar.fields.keys()
```

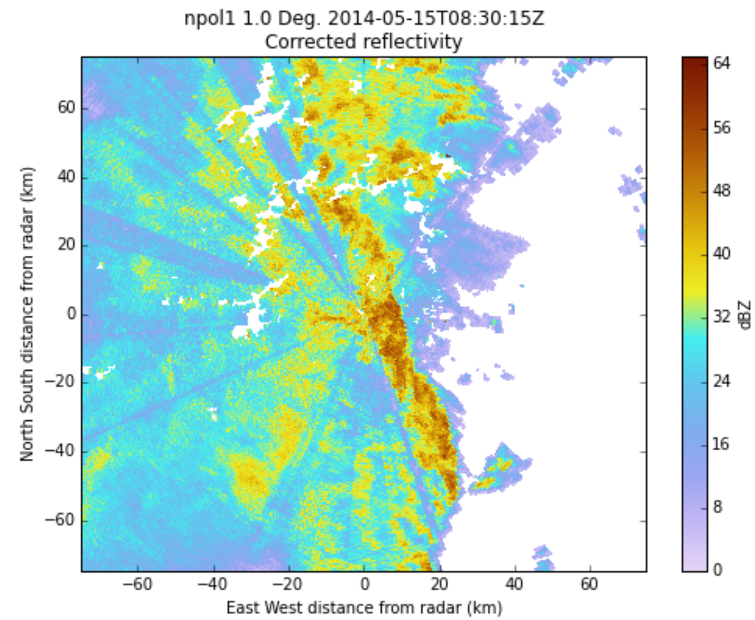
```
[u'DC', u'DZ', 'FH', u'FL', u'HD', u'PF', u'PH', u'RH', 'method', 'NW', u'AD', u'ZD', u'AH',
'rain', u'ZC', u'VR', u'KD', u'SR', 'MI', 'MU', 'MW', 'D0']
```

In [11]:
```
display = pyart.graph.RadarDisplay(retrieve.radar)
swp = 0
lim = [-80, 80]
fig = plt.figure(figsize=(16, 14))
ax1 = fig.add_subplot(221)
display.plot_ppi('ZC', swp, vmin=0, vmax=70, cmap='gist_ncar')
display.cbs[0].ax.set_ylabel('Reflectivity (dBZ)')
display.set_limits(xlim=lim, ylim=lim)
ax2 = fig.add_subplot(222)
hidcolor = dualpol.HidColors()
display.plot_ppi('FH', swp, vmin=0, vmax=10, cmap=hidcolor.cmaphid)
display.cbs[1] = hidcolor.adjust_fhc_colorbar_for_pyart(display.cbs[1])
display.set_limits(xlim=lim, ylim=lim)
ax3 = fig.add_subplot(223)
display.plot_ppi('rain', swp, vmin=0, vmax=150, cmap='GnBu')
display.set_limits(xlim=lim, ylim=lim)
ax4 = fig.add_subplot(224)
display.plot_ppi('method', swp, vmin=0, vmax=5, cmap=hidcolor.cmapmeth)
display.cbs[3] = hidcolor.adjust_meth_colorbar_for_pyart(display.cbs[3])
display.set_limits(xlim=lim, ylim=lim)
plt.tight_layout()
```



Python Polarimetric Radar Beam Blockage Calculation (PyBlock)

https://github.com/nasa/PyBlock

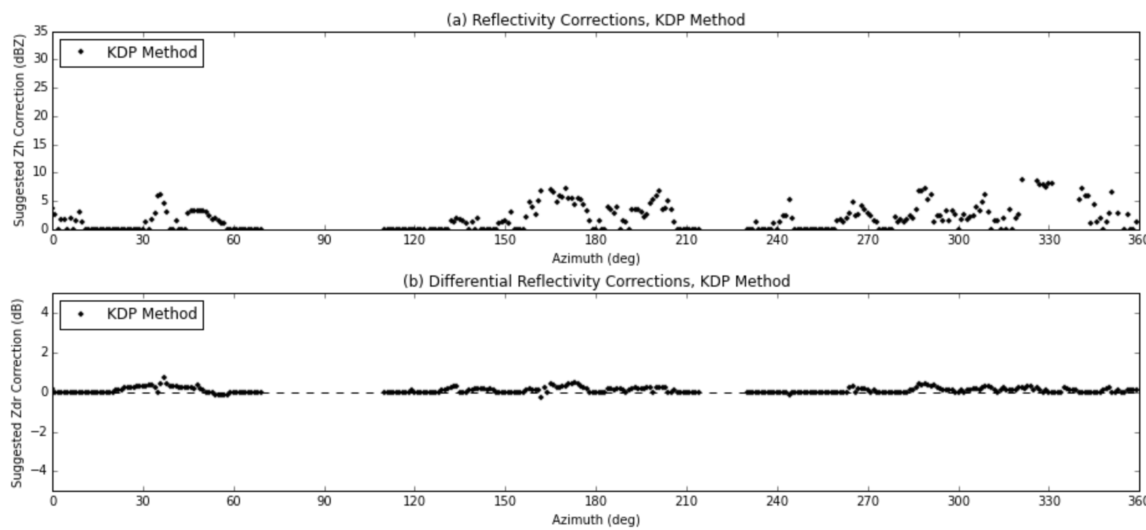


Goal

Calculate beam blockage and estimate corrections needed for polarimetric radar data

Features

- KDP Method from Lang et al. (2009)
- Fully Self-Consistent Method from Giangrande and Ryzhkov (2005)
- Interfaces w/ DualPol, Py-ART, CSU_RadarTools
- Process one volume or an entire field campaign's worth of radar volumes
- Output results to image or file
- Demonstration notebook

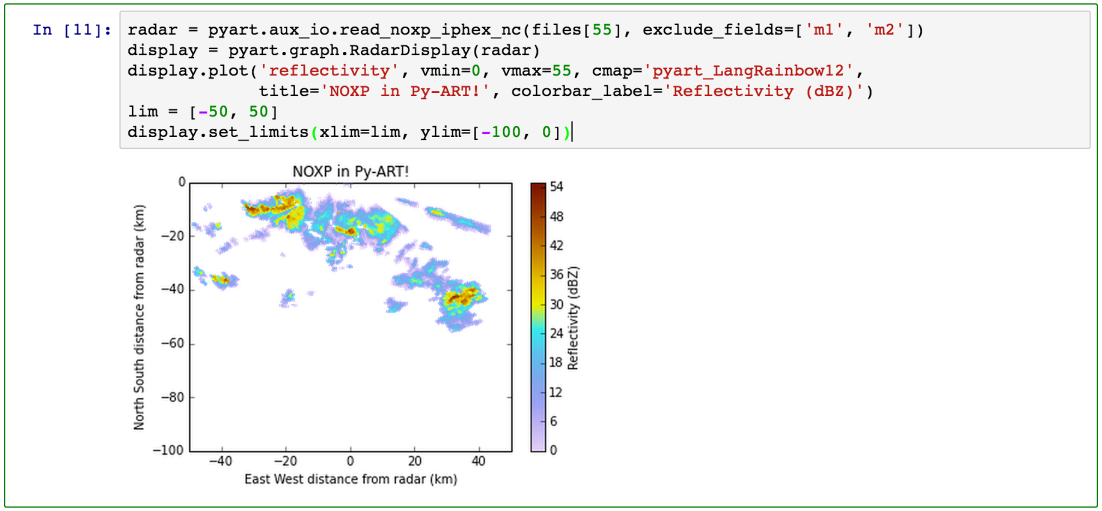


Collaborations

Py-ART Contributions

- Color blindness friendlier rainbow color table
- NOXP radar data reader
- Automated dealiasing testing (Poster session #3 today)

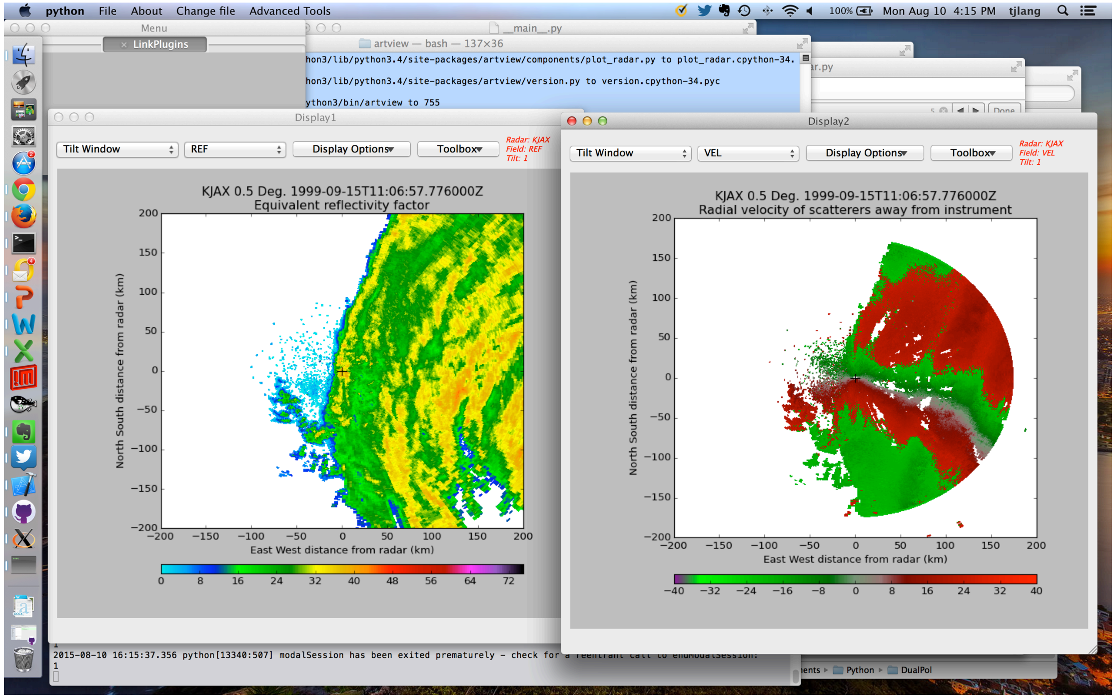
Argonne NATIONAL LABORATORY



ARTview Contributions

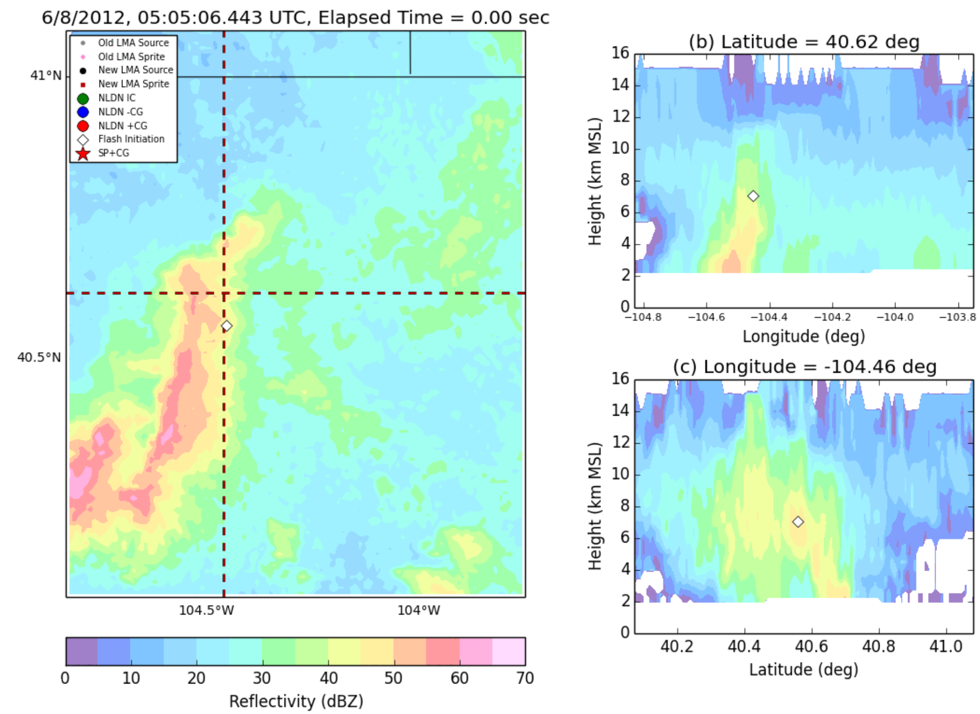
- Minor feature additions
- Code cleanup/bug fixes
- Testing and evaluation

UNIVERSITY OF WYOMING

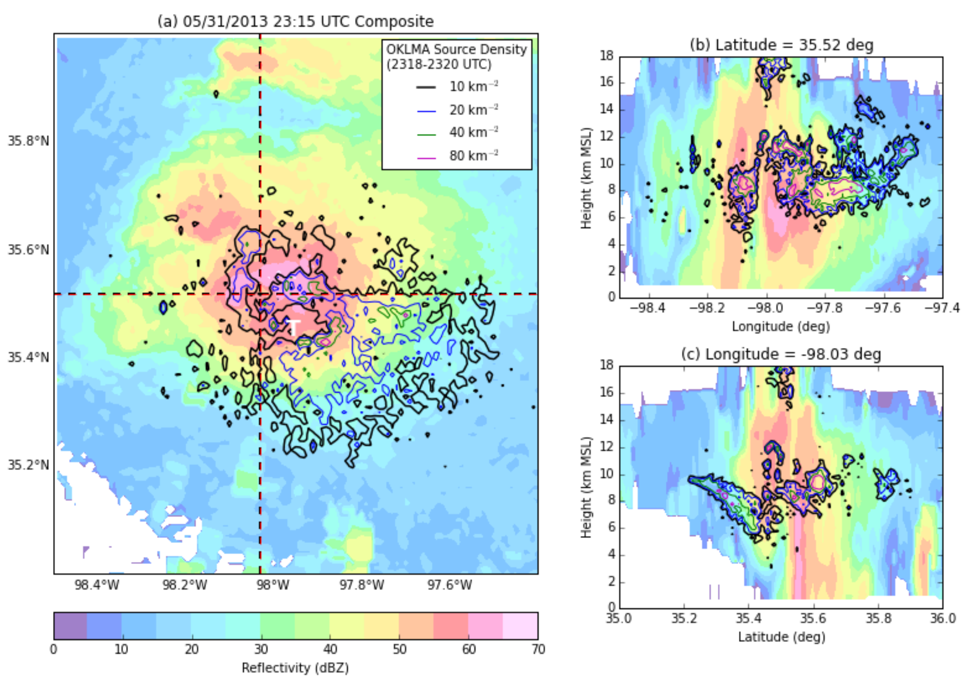


Putting it all together …

MMM-Py combined with in-house Python modules that merge MRMS and Lightning Mapping Array (LMA) data to study storms that produce large charge moment change lightning and/or sprites



- Colorado sprite-producing storm (2012)
- MRMS w/ animated Colorado LMA sources



- El Reno storm (2013)
- Tornadic Stage
- MRMS w/ Oklahoma LMA source densities

Putting it all together …

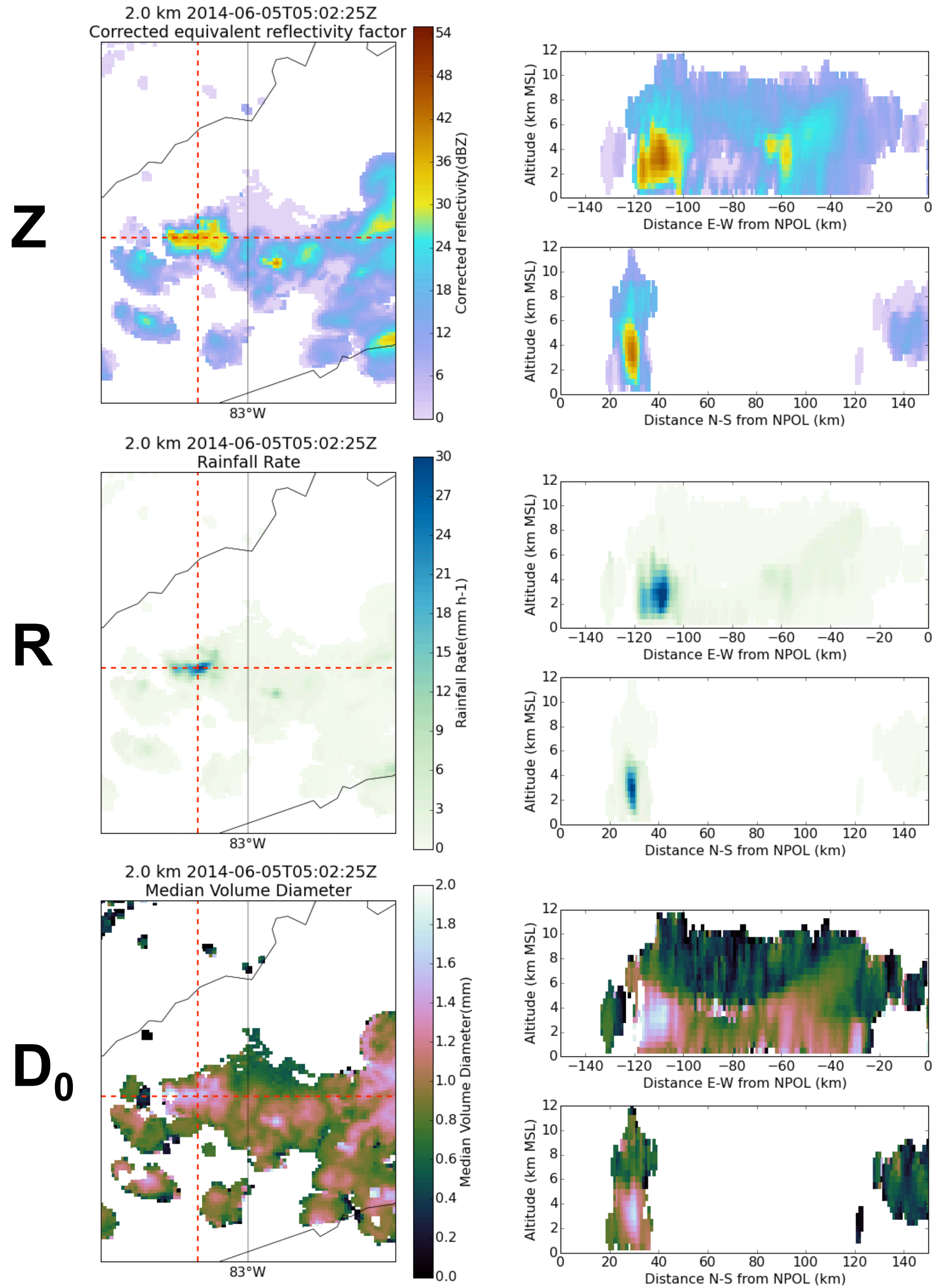
IPHEx Field Campaign Data Fusion in support of GPM GV

<u>Radars</u>

Mixture of research and ops: NPOL, NOXP, KCAE, KGSP, KHTX, KMRX, KRAX, KFFC

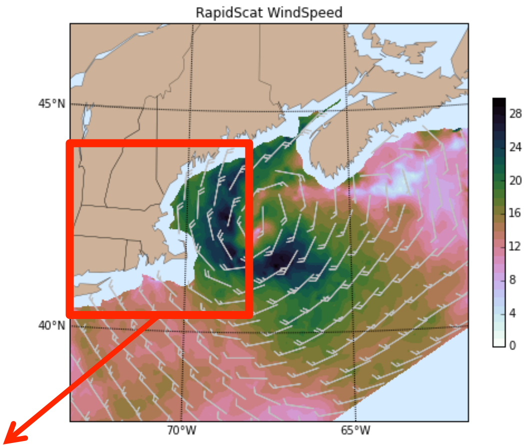
<u>Tasks</u>

- Py-ART to ingest and merge radar volumes onto common grid
- DualPol to compute rainfall and DSD parameters
- CSU_RadarTools to mask insect echoes & high differential phase texture, and despeckle remainder



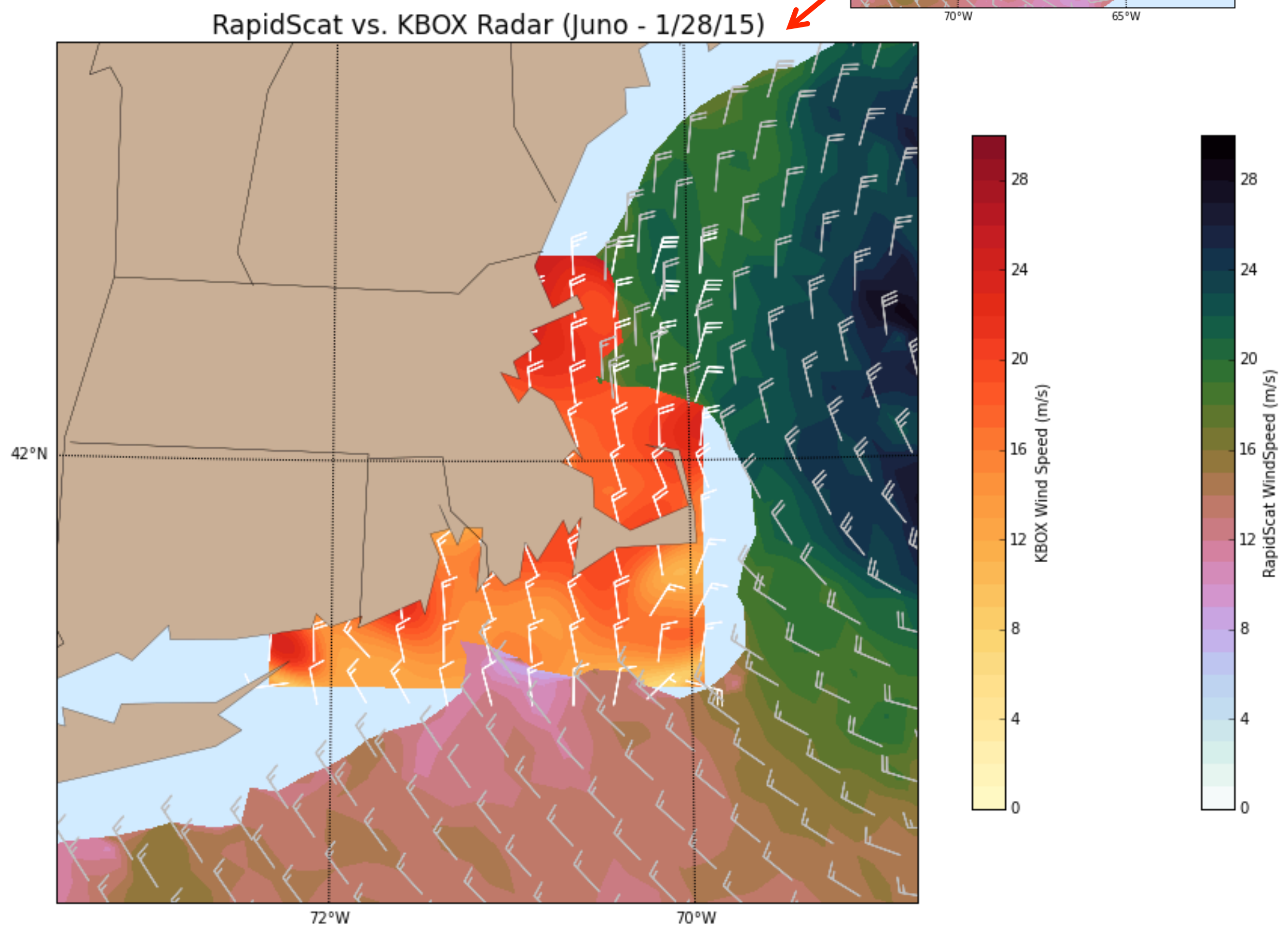
Putting it all together …

Exploring the best ways to compare scatterometers to ground-based Doppler radars



<u>Tasks</u>

- Pydap to ingest RapidScat data via OPeNDAP
- Py-ART to ingest radar data and dealias velocity
- SingleDop to perform 2D low-level wind retrievals
- Also: DualPol, CSU_RadarTools



Summary

Timothy Lang
@tjlang

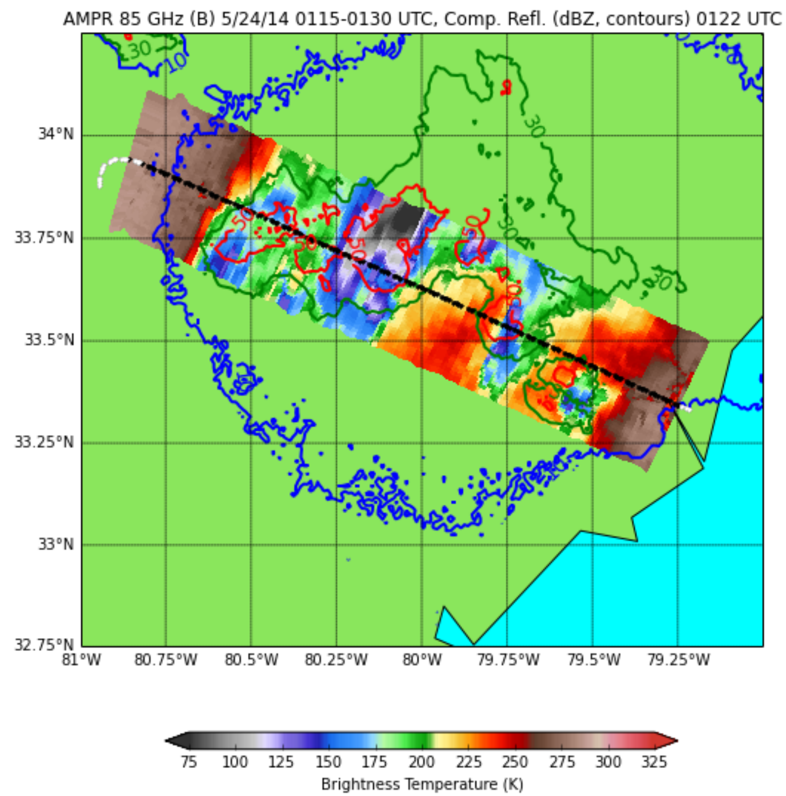
Just completed a preliminary case study using Python 3 @Py_ART, ARTview (zenodo.org/record/27358#….), and SingleDop (github.com/nasa/SingleDop)

8/11/15, 10:53 AM

<u>Six Radar Modules</u>

1. MMM-Py
2. PyTDA
3. SingleDop
4. CSU_RadarTools
5. DualPol
6. PyBlock

\+ PyAMPR!



Open source, play nice with Py-ART, support Python 3, & are available on GitHub right now (nasa & CSU-Radarmet)

Contact Info:
timothy.j.lang@nasa.gov

The Future

Major coding done for now, but some possible ideas for directions to go:

- Merge into MSFC_RadarTools?
- Integration of components within Py-ART or wradlib?
- Make part of some future scikits-radar?
- NASA airborne radar module or interface?

But for now … http://code.nasa.gov takeover!